

Patuxent River Basin Summary

Final Version for 1985-2002 Data

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Prepared by: Basin Summary Team and Chesapeake Bay Program
Tidal Monitoring and Analysis Workgroup
Contact: Beth Ebersole, Maryland Department of Natural Resources
bebersole@dnr.state.md.us

Patuxent River Basin Characteristics

The Patuxent River is the largest river completely in Maryland. Its basin drains 932 square miles of land within Maryland's Western Shore (Figure PXT1). This area includes portions of St. Mary's, Calvert, Charles, Anne Arundel, Prince George's, Howard, and Montgomery Counties. Three main streams drain into the upper Patuxent River: the Little Patuxent, which drains much of the newly urbanized area of Columbia; the Middle Patuxent, which drains agricultural lands in the northern part of its drainage and the outer suburban areas of Columbia in the southern part of its basin; and the (upper) Patuxent River, which has remained primarily agricultural. The Patuxent River basin lies both in the Piedmont and Coastal Plain physiographic provinces.

The Patuxent basin lies between two large metropolitan areas—Baltimore, Maryland and Washington, D.C. Consequently, the watershed has gone through significant suburban development in the past few decades. The 2000 census population for the basin was 618,000 people. The thriving suburban communities of Columbia and Laurel have developed along the Interstate 95 corridor, which bisects the upper half of the basin. The town of Bowie has also undergone much recent development.

Land use in the basin is 44 percent forest, 30 percent urban, and 26 percent agriculture. The land above the fall line is more urbanized than that below the fall line.

Urban land use comprises 30 percent of the basin. Over 80 percent of the housing in the basin is urban, with most of the remaining housing in rural areas. Concurrent with this large amount of urban housing is a heavy reliance on municipal water and sewage systems. In addition, 77 percent of the basin's housing relies on municipal sewage system and 81 percent of the housing uses a public water source. Contributions from point sources make up roughly one third of the nutrient loadings to the Patuxent River. There are more than 20 sewage plants in the basin (Figure PXT2). Tributary strategy goals for BMPs associated with urbanization have been established to reduce non point source loads from urbanized lands. Good progress has been made toward these.

About a quarter (26 percent) of the Patuxent River basin is agricultural land. A series of Best Management Practices (BMPs) have been planned to help reduce non point source loads from agricultural lands. BMP implementation for conservation tillage and sediment control plans are making good progress toward Tributary Strategy goals. As of 1998,

progress had been slower for other issues, such as animal waste management, cover crops, grass buffers, nutrient management plans, runoff control, and stream protection.

Figure PXT1 – 2000 Land Use in the Patuxent River Basin

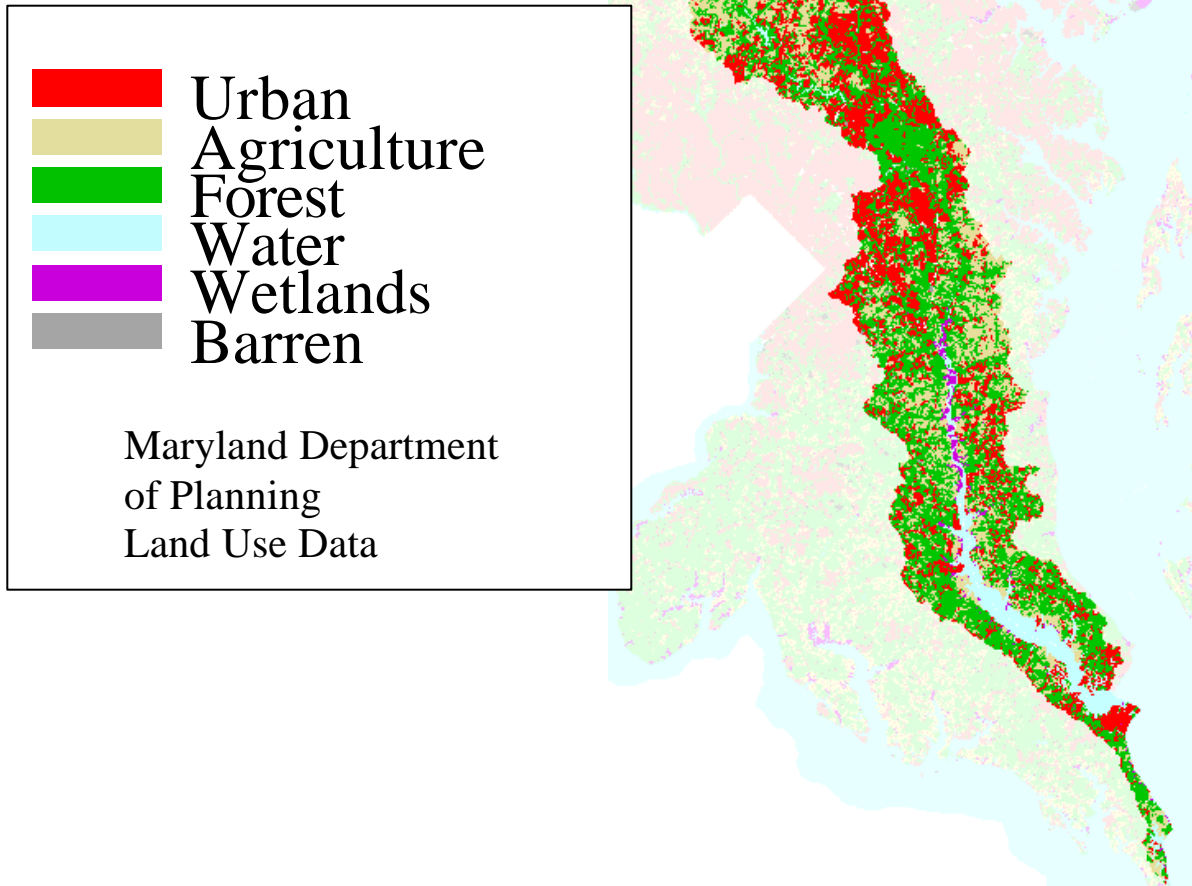
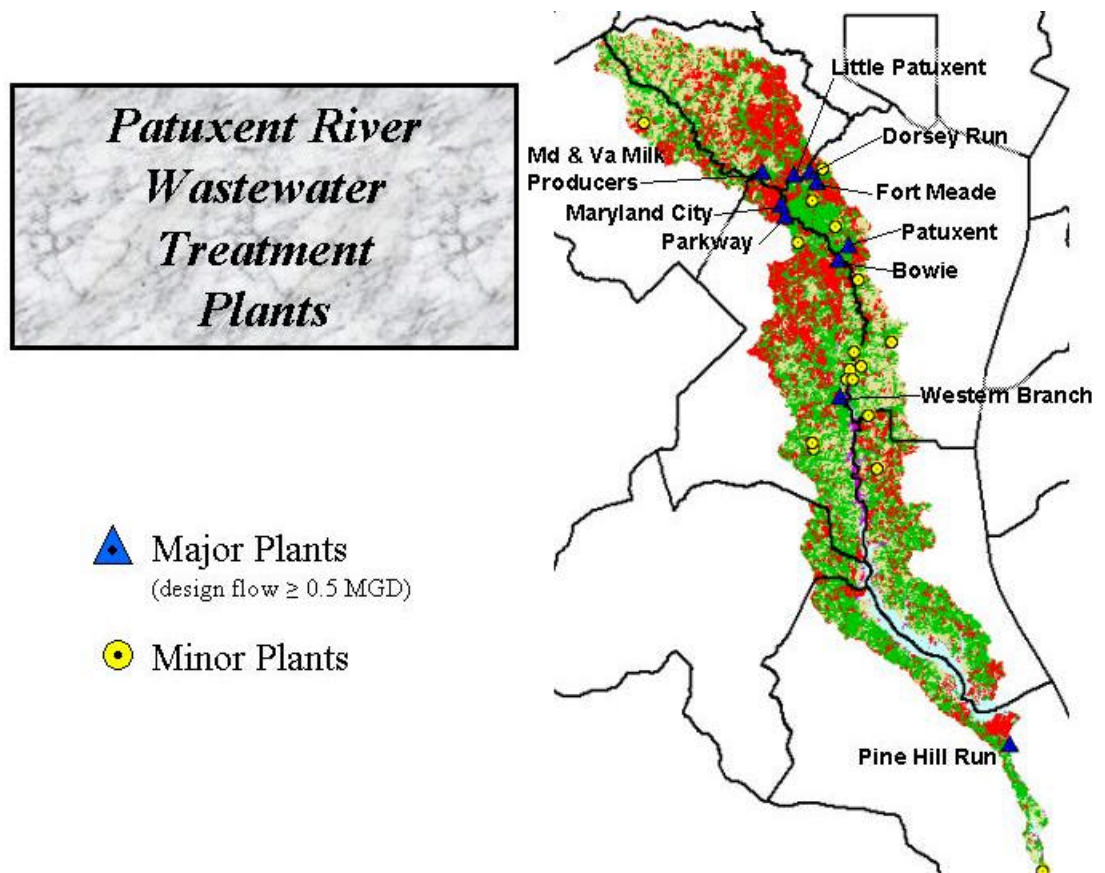


Figure PXT2 – Wastewater Treatment Plants in the Patuxent River Basin



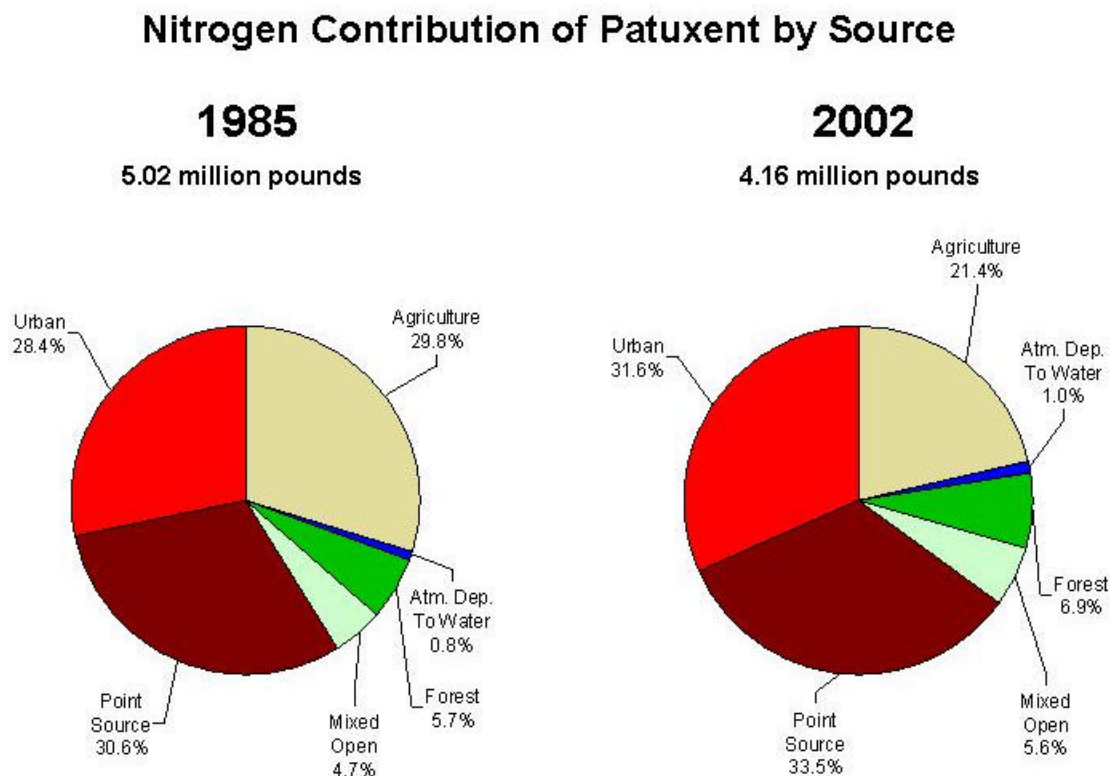
goals with respect to marine pumpouts, shore erosion, septic connections, and stormwater management conversions and retrofits. As of 1998, progress had not been good with respect to enhanced stormwater management, erosion and sediment control, septic pumping, and urban nutrient management.

Almost half of the basin was forested as of 1994 (46 percent). Of BMPs related to forests, forest harvest practices and tree planting have not yet been widely implemented.

As of 2002, the most significant contributor of nitrogen in the Patuxent River basin was point sources (34 percent) (Figure PXT3). Following that were urban sources (32 percent) and agriculture (21 percent). For phosphorus, the largest contributor was urban sources (36 percent), followed by point sources (30 percent) and agriculture (22 percent) (Figure PXT4). Agriculture was the dominant source of total suspended solids (55 percent) followed by urban sources (28 percent) (Figure PXT5).

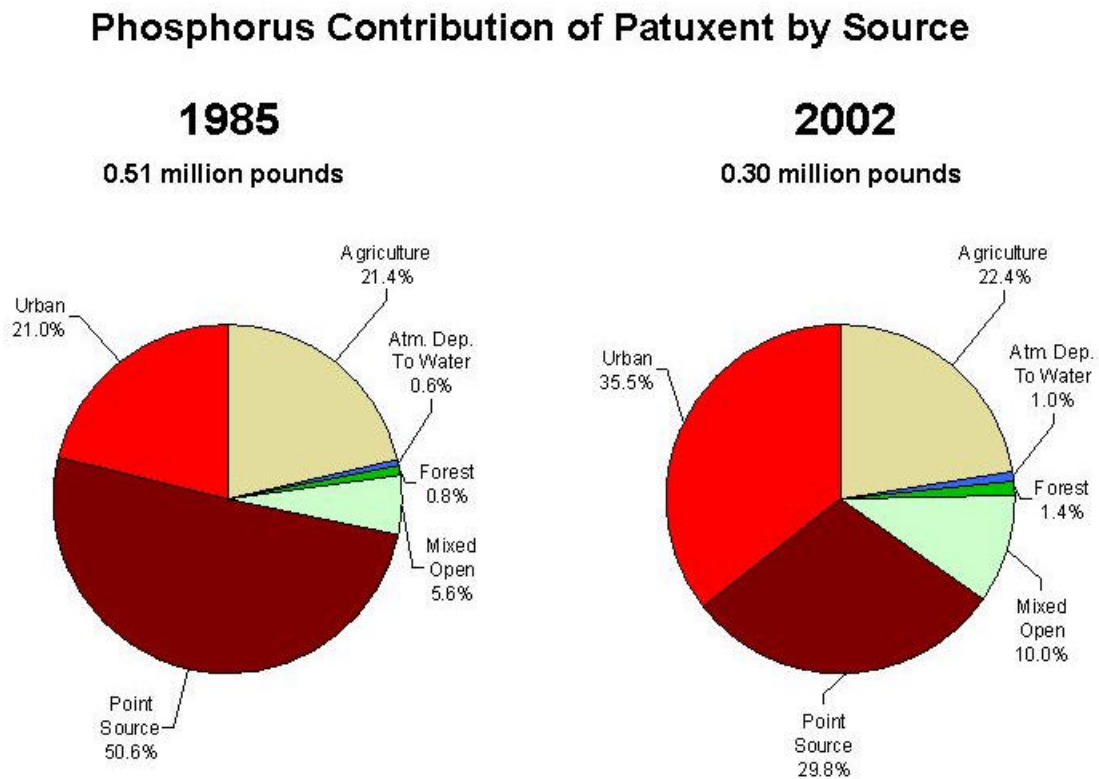
The watershed supports more than 100 species of fish in its freshwater streams and brackish waters, including largemouth bass, chain pickerel, catfish, weakfish and bluefish. The Patuxent also supports an important commercial and recreational blue crab fishery.

Figure PXT3 – 1985 and 2002 Nitrogen Contribution to the Patuxent River by Source.



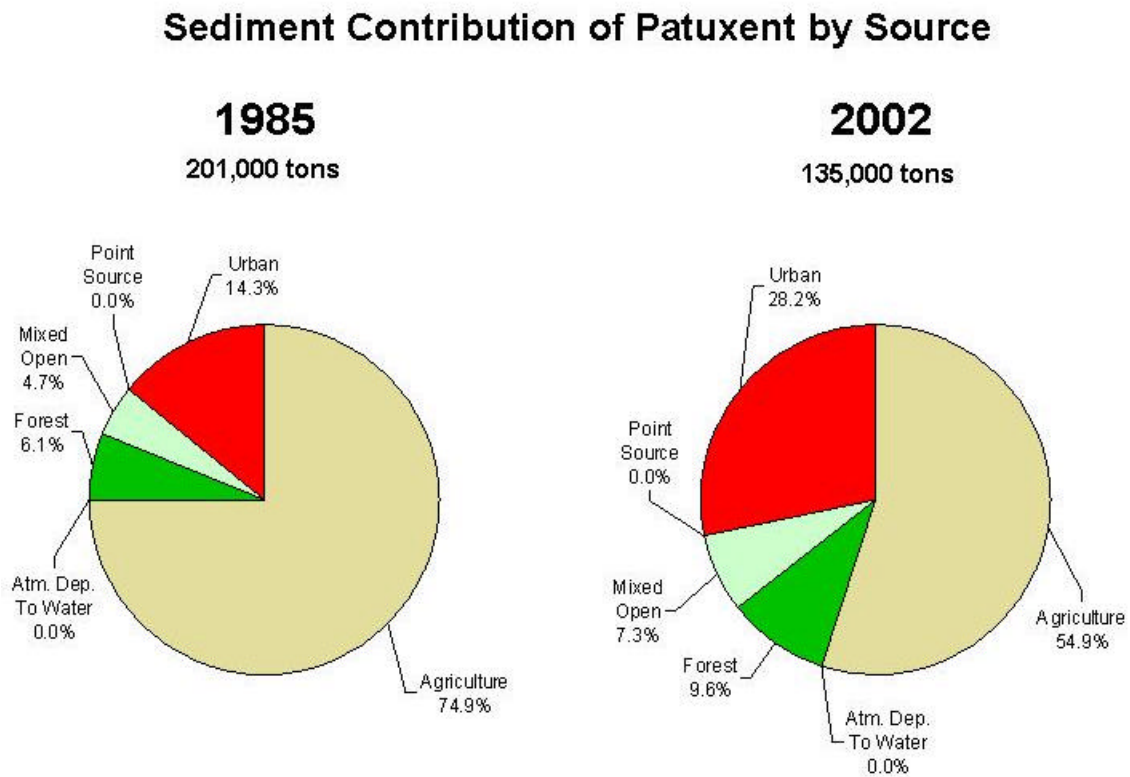
Source: Chesapeake Bay Program Phase 4.3 Watershed Model

Figure PXT4 – 1985 and 2002 Phosphorus Contribution to the Patuxent River by Source.



Source: Chesapeake Bay Program Phase 4.3 Watershed Model

Figure PXT5 – 1985 and 2002 Sediment Contribution to the Patuxent River by Source.



Source: Chesapeake Bay Program Phase 4.3 Watershed Model

Overview of Monitoring Results

Water and Habitat Quality

Non-tidal Water Quality Monitoring Information Sources

Much useful information on non-tidal water quality is available on the Internet. The State of Maryland's Biological Stream Survey (MBSS) basin fact sheets and basin summaries are available at:

http://www.dnr.state.md.us/streams/mbss/mbss_fs_table.html

MBSS also reports stream quality information summarized by county at:

http://www.dnr.state.md.us/streams/mbss/county_pubs.html In addition to these reports and fact sheets, detailed and more recent information and data are also available on the MBSS website: <http://www.dnr.state.md.us/streams/mbss>

Information on Prince George's County water quality monitoring and stream assessments are available at:

http://www.co.pg.md.us/Government/AgencyIndex/DER/PPD/Environment_Protection/water_quality.asp?h=20&s=40&n=50&n1=150

Water quality information collected by Maryland's volunteer Stream Waders is available at: http://www.dnr.state.md.us/streams/mbss/mbss_volun.html

Long-term Water Quality Monitoring

Good water quality is essential to support the animals and plants that live or feed in the Patuxent tributaries. Important water quality parameters are measured at 14 long-term monitoring stations in the Patuxent basin. Parameters measured include nutrients, algal abundance, total suspended solids, water clarity (Secchi depth), and dissolved oxygen.

Current status is determined based on the most recent three-year period (2000-2002). For dissolved oxygen, the current levels are compared to ecologically meaningful thresholds to assign a status of good, fair, or poor. Thresholds have not been established for the other parameters, so the current data are compared to a baseline data set, and assigned a status of good, fair, or poor, which is only a *relative* status compared to the baseline data. Long-term trends are determined using a non-parametric test for trend (the Seasonal Kendall test). For a detailed description of the methods used to determine status and trends, see http://www.dnr.state.md.us/bay/tribstrat/status_trends_methods.html.

Although total nitrogen and total phosphorus levels have declined during the 1985-2002 period, algal abundance has not decreased. In fact, at some stations, algal abundance has increased. Total suspended solids have increased at Jackson Landing, but decreased at a few of the downstream stations. Water clarity remains poor at many stations. Dissolved oxygen levels are fair at most stations, but poor at Jack Bay, and good at Lower Marlboro and Nottingham.

Figure PXT6 – Total Nitrogen Concentrations in the Patuxent River Basin

Total Nitrogen Concentrations: Patuxent River

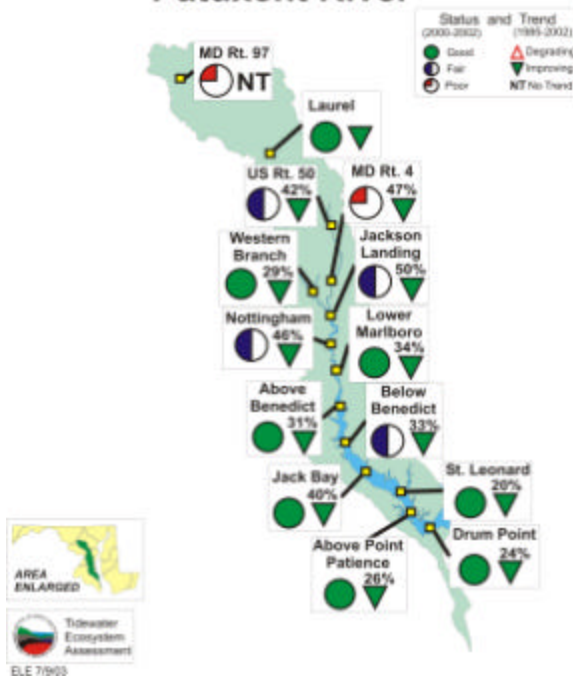


Figure PXT7 – Total Phosphorus Concentrations in the Patuxent River Basin

Total Phosphorus Concentrations: Patuxent River

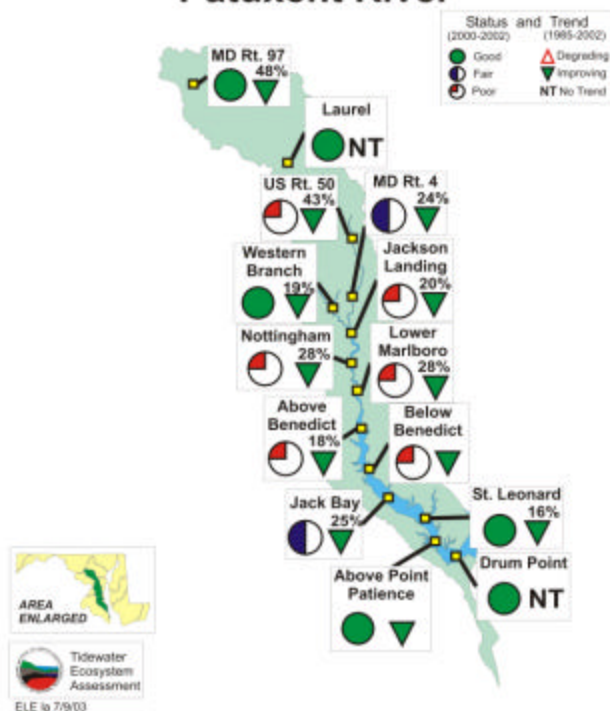


Figure PXT8 – Abundance of Algae in the Patuxent River Basin

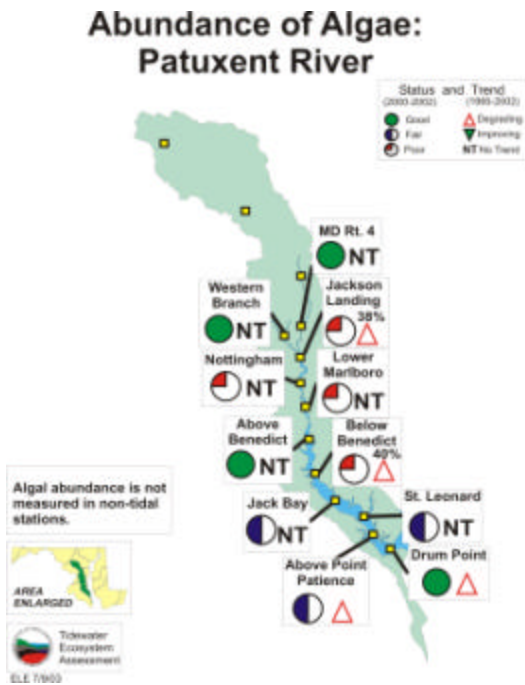


Figure PXT9 – Total Suspended Solids Concentrations in the Patuxent River Basin

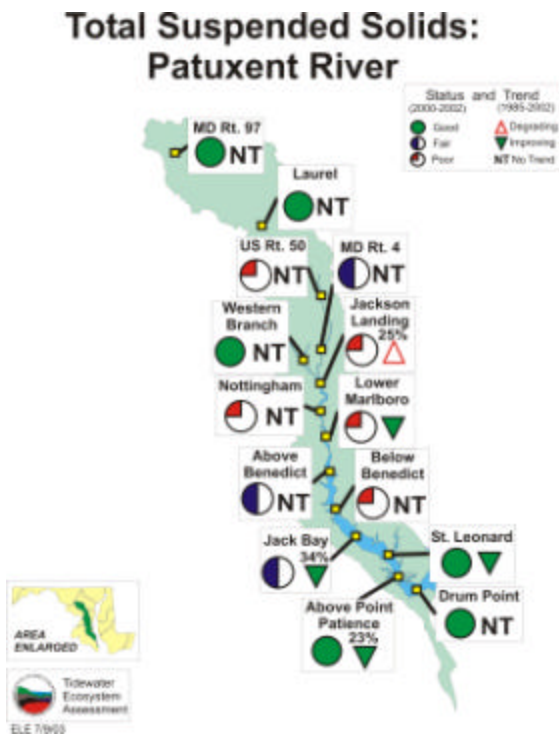


Figure PXT10 – Water Clarity (Secchi Depth) in the Patuxent River Basin

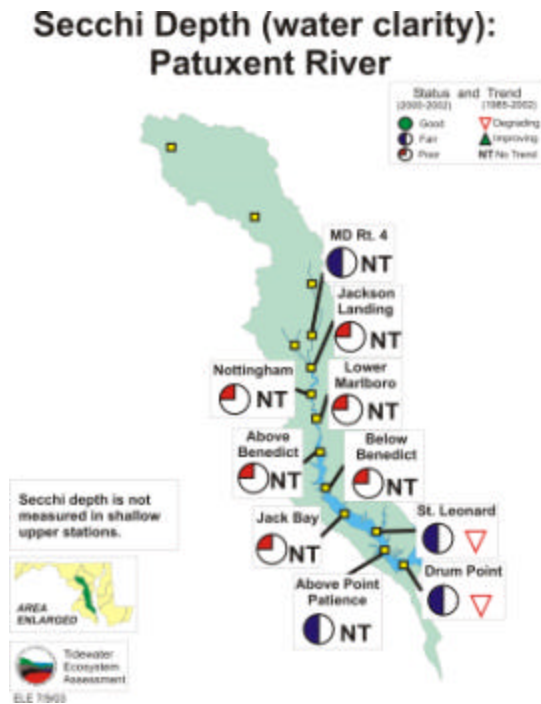
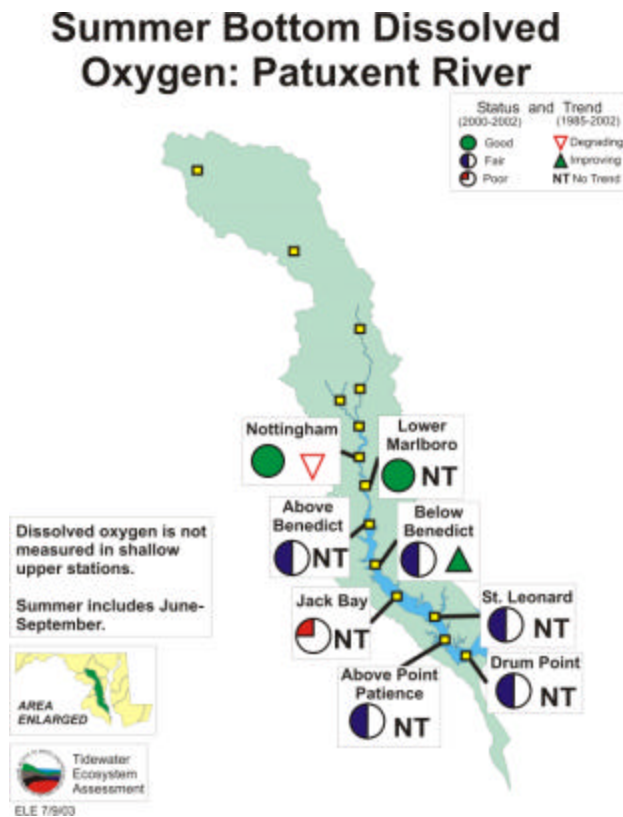


Figure PXT11 –Dissolved Oxygen in the Patuxent River Basin



SAV (Bay Grasses)

The well-defined linkage between water quality and submerged aquatic vegetation (SAV) distribution and abundance make SAV communities good barometers of the health of estuarine ecosystems. SAV is important not only as an indicator of water quality, but it is also a critical nursery habitat for many estuarine species. Blue crab post-larvae are 30 times more abundant in SAV beds than adjacent unvegetated areas. Similarly, several species of waterfowl are dependant on SAV as food when they over-winter in the Chesapeake region.

The Chesapeake Bay Program has developed new criteria for determining SAV habitat suitability of an area based on water quality. The **A**Percent Light at Leaf[®] habitat requirement assesses the amount of available light reaching the leaf surface of SAV after being attenuated in the water column and by epiphytic growth on the leaves themselves. The document describing this new model is found on the Chesapeake Bay Program website (www.chesapeakebay.net/pubs/sav/index.html). The older **A**Habitat Requirements[®] of five water quality parameters are still used for diagnostic purposes. Re-establishment of SAV is measured against the **A**Tier 1 Goal[®], an effort to restore SAV to any areas known to contain SAV from 1971 to 1990.

The tidal fresh Patuxent River has seen a remarkable growth of SAV since 1993 (www.vims.edu/bio/sav/). In fact, 1993 to 1998 saw the SAV coverage exceeding the Tier I goal of 14 acres, and 1994 to 1998 the SAV abundance was a factor of 10 over the goal (Figure PXT1). However, due to weather delays, the aerial survey was not able to cover the upper Patuxent in 1999. The 2001 aerial survey indicated there were 205 acres of SAV, the most ever recorded and 1472 percent of the Tier I goal. Ground-truthing by the Maryland Department of Natural Resources, Patuxent River Park, Jug Bay Wetlands Sanctuary and citizens has found 16 species of SAV in this region with the most commonly identified ones being hydrilla (*Hydrilla verticillata*), common waterweed (*Elodea canadensis*), and coontail (*Ceratophyllum demersum*). There are five water quality-monitoring stations in this area (near the Route 4 bridge, the confluence of Western Branch, near the Western Branch Waste Water Treatment Plant, near the ruins of the old railroad bridge at Jug Bay Wetlands Sanctuary and near the confluence of Kings Creek).

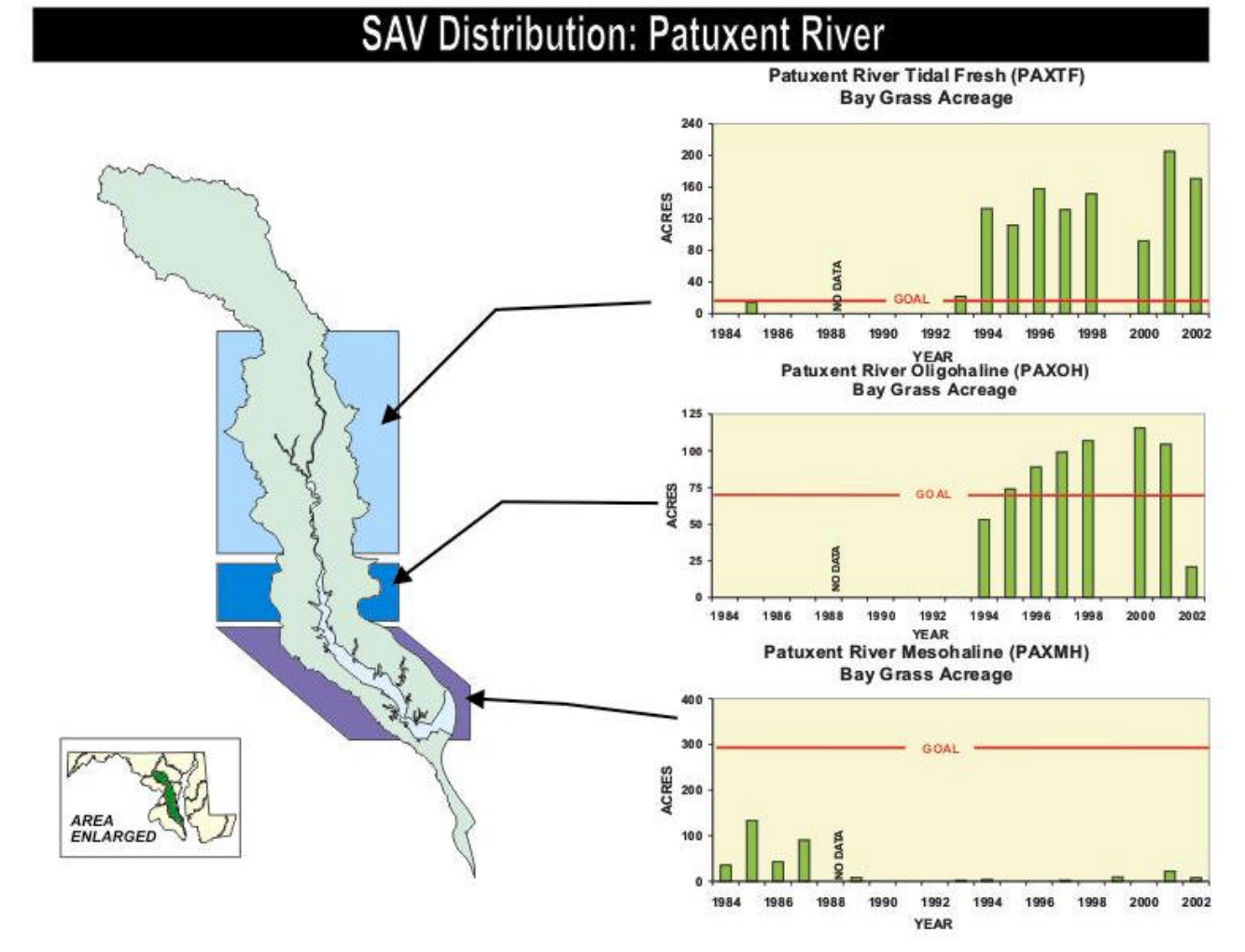
The data from these sources indicate that most SAV habitat requirements fail for this region (percent light at leaf, light attenuation, concentration of suspended solids and phosphorous), with only algae levels being borderline (nitrogen levels are not applicable to the tidal fresh regions). The most likely explanation for the growth of SAV even though there are poor water quality conditions is that the plants are growing on very shallow mudflats, which provides them with enough light to grow.

The middle Patuxent area has also seen remarkable re-vegetation in recent years as mapped by the Virginia Institute of Marine Science annual aerial survey.

(www.vims.edu/bio/sav/). Beginning in 1994, when SAV first reappeared in this region with 53 acres, the SAV coverage increased to 104 acres in 2001 (Figure PXT12). Ground-truthing by MD-DNR, Patuxent River Park, and citizens have found 12 species of SAV in this region with the most commonly identified ones being coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*), and curly pondweed (*Potamogeton crispus*). There are two monitoring stations in this area, one near Short Point and the other just north of Cedarhaven. The water quality data from these sites indicates that this region fails most SAV habitat requirements (percent light at leaf, light attenuation, suspended solids, nitrogen, and phosphorous concentrations), with algae levels being borderline.

The lower Patuxent River has not had a recovery similar to the upper two reaches. The VIMS annual aerial survey (www.vims.edu/bio/sav/) has found only very small SAV beds (less than 10 acres) since 1987 (Figure PXT12), though 2001 had 22 acres. This is well below the Tier I goal of 355 acres. The few beds that have been found in the last three years were in the Solomon's Island and Hungerford Creek areas. Ground-truthing by citizens, NOAA, EPA, Chesapeake Biological Laboratory and Patuxent River Park staff has found (in order of frequency) horned pondweed (*Zannichellia palustris*), sago pondweed (*Potamogeton pectinatus*), milfoil (*Myriophyllum spicatum*), widgeon grass (*Ruppia maritima*), wild celery (*Vallisneria americana*) and common waterweed (*Elodea sp.*). There are five water quality monitoring stations in this reach of the Patuxent River, located near Long Point, Jack Bay, mouth of St. Leonard's Creek, mouth of Cuckold Creek, and one station between Drum and Fishing Points. Data from these stations indicate that suspended solid, algae and nitrogen levels all pass the SAV habitat requirements. Light attenuation, percent light at leaf, and phosphorous are borderline relative to the habitat requirements.

Figure PXT12 –Bay Grasses (Submerged Aquatic Vegetation) Distribution in the Patuxent River Basin



Benthic Community

The benthic community forms an integral part of the ecosystem in estuarine systems. For example, small worms and crustaceans are key food items for crabs and demersal fish, such as spot and croaker. Suspension feeders that live in the sediments, such as clams, can be extremely important in removing excess algae from the water column. Benthic macroinvertebrates are reliable and sensitive indicators of estuarine habitat quality.

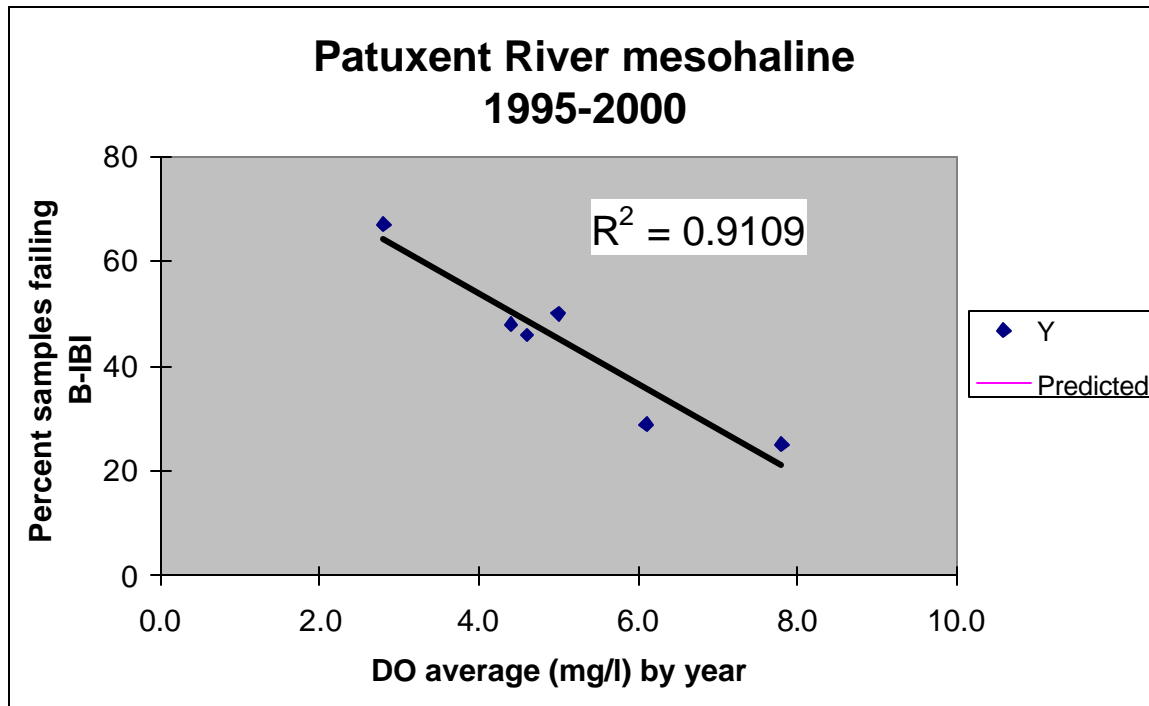
Benthic monitoring includes both probability-based sampling (sampling sites are selected at random) and fixed station sampling (the same site is sampled every year). A benthic index of biotic integrity (B-IBI) is determined for each site (based on abundance, species diversity, etc.). The B-IBI serves as a single-number indicator of benthic community health. For a more details on the methods used in the benthic monitoring program see <http://esm.versar.com/Vcb/Benthos/backgrou.htm>

During the period 1995-2000, benthic community condition was best in the oligohaline portion of the Patuxent River (Figure PXT13), and worst in the tidal freshwater, although only three samples were collected in the tidal freshwater segment during this period. Benthic condition in the mesohaline portion of the river varied according to year, with percent samples failing the B-IBI strongly correlated with low dissolved oxygen stress (Figure PXT14). Degradation in the mesohaline Patuxent River was due primarily to low abundance, biomass, and species diversity, and to low biomass of pollution-sensitive species, which are typically representative of mature communities in the absence of low dissolved oxygen stress.

Figure PXT13. Number of sites failing the B-IBI, probabilities and standard errors (SE) of observing degraded benthos, non-degraded benthos, or benthos of intermediate condition (indeterminate for low salinity habitats) for Patuxent River Basin segments, 1995-2000. Segments codes: TF = tidal freshwater, OH = oligohaline, MH = mesohaline. Probabilities (for all segments) and standard errors (for segments with ≥ 5 samples) were adjusted according to Agresti and Caffo (2000). Standard errors were used to calculate 67 percent (\pm SE) and 90 percent ($\pm 1.65 \times$ SE) confidence limits. Exact confidence limits were used for segments with < 5 samples, and are not shown in the tables. Adjusted probabilities do not add to 100 percent.

Segment	River	Number of Sites	Sites with B-IBI<3.0	P Deg.		P Non-deg.		P Interm.	
PAXTF	Patuxent	3	3	71.4	-	28.6	-	28.6	-
PAXOH	Patuxent	14	5	27.8 (10.6)		66.7 (11.1)		16.7 (8.8)	
PAXMH	Patuxent	134	60	37.0 (4.1)		42.8 (4.2)		21.7 (3.5)	

Figure PXT14. Percentage of samples failing the B-IBI (B-IBI <3.0) in the mesohaline segment of the Patuxent River as a function of near-bottom dissolved oxygen (DO) concentrations averaged by site and year.



Three of the four long-term benthic monitoring stations in the Patuxent River showed degrading trends in benthic community condition, 1985-2000. These degrading Patuxent River stations varied in benthic condition and degree of change (Figure PXT13). Station 74, in the Chalk Point region, exhibited best status. A factor contributing to the declining B-IBI at this station was a significantly increasing trend in total abundance of organisms above reference levels, a pattern symptomatic of intermediate levels of eutrophication. It is possible that the degrading trend in B-IBI at Station 74 might be related to increasing Chlorophyll *a* concentrations. Chlorophyll *a* in the mesohaline Patuxent River has been increasing in the surface mixed layer annually. Station 74 is located in shallow water where low dissolved oxygen has historically not been a problem. Although the station is under the thermal influence of the Chalk Point power plant, no significant impacts on benthos from the thermal discharge have been documented to date. Likewise, the oil spill of April 2000 in Swanson Creek, in the vicinity of Chalk Point, did not show impacts on the benthic community at this site.

Station 77, in the Holland Cliff area, had the most pronounced decline in the B-IBI (Table 13). The two major contributing factors to this trend were a decrease in total biomass and an increase in percent abundance of pollution-indicative species. The decrease in total biomass was attributed to a decrease in the abundance of the bivalve *Macoma balthica*. Abundance changes in *Macoma* were associated with salinity changes in the river. Long-term salinity records shows a decrease in summer salinity below 7 ppt, the approximate limit of distribution of *Macoma* in the Chesapeake Bay. Spring salinity values decreased below 1 ppt. These changes in salinity occurred during the recruitment

period, and may be linked to a reported 57 percent flow increase in the Patuxent River since 1985.

The declining trend in B-IBI at Station 71 (Figure PXT13) can most likely be attributed to increasing stress from low dissolved oxygen, possibly influenced by the very low dissolved oxygen values that were recorded in the lower Patuxent River during the Summer of 2000. Station 71 is located in a deep area of the mesohaline Patuxent River near Broomes Island. The benthic community at this station exhibited significant decreases in total abundance and biomass over time, factors that are usually linked to stress from low dissolved oxygen.

In summary, benthic community condition in the Patuxent River during the monitoring period 1985-2000 exhibited long-term trends that appeared to be associated with low dissolved oxygen stress in the lower portion of the estuary, possibly with eutrophic conditions in the Chalk Point region, and with changes in river flow and salinity patterns controlling clam populations further upstream.

Nutrient Limitation

Like all plants, phytoplankton need nitrogen, phosphorus, light, and suitable water temperatures to grow. If light is adequate and the water temperature is appropriate, phytoplankton will continue to grow as long as unlimited amounts of nutrients are available. If nutrients are not unlimited, then the ratio of nitrogen to phosphorus affects phytoplankton growth. (Phytoplankton generally use nitrogen and phosphorus at a ratio of 16:1, that is, 16 times as much nitrogen is needed as phosphorus. This is called the Redfield ratio.) If one of the nutrients is not available in the adequate quantity, phytoplankton growth is 'limited' by that nutrient. If both nutrients are available in enough excess (regardless of the relative proportion of them) that the phytoplankton can not use them all even when they are growing as fast as they can under the existing temperature and light conditions, then the system is 'nutrient saturated.'

Nitrogen limitation occurs when there is insufficient nitrogen, i.e., there is excess phosphorus. Nitrogen limitation often happens in the summer and fall after stormwater flows are lower (so less nitrogen is being added to the water) and some of the nitrogen has already been used up by phytoplankton growth during the spring. If an area is nitrogen limited, then adding nitrogen will increase phytoplankton growth.

Phosphorus limitation occurs when there is insufficient phosphorus, i.e. there is excess nitrogen. If an area is phosphorus limited, then adding phosphorus will increase phytoplankton growth. Phosphorus limitation occurs in some locations in the spring when large amounts of nitrogen are added to the estuary from stormwater flow.

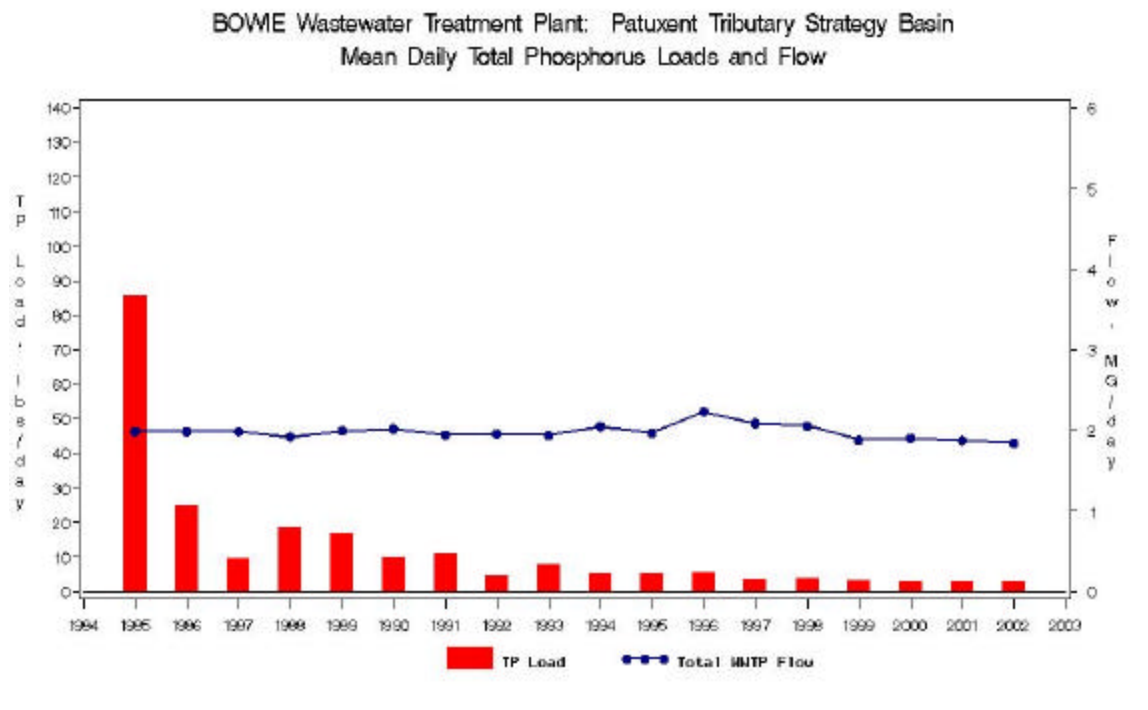
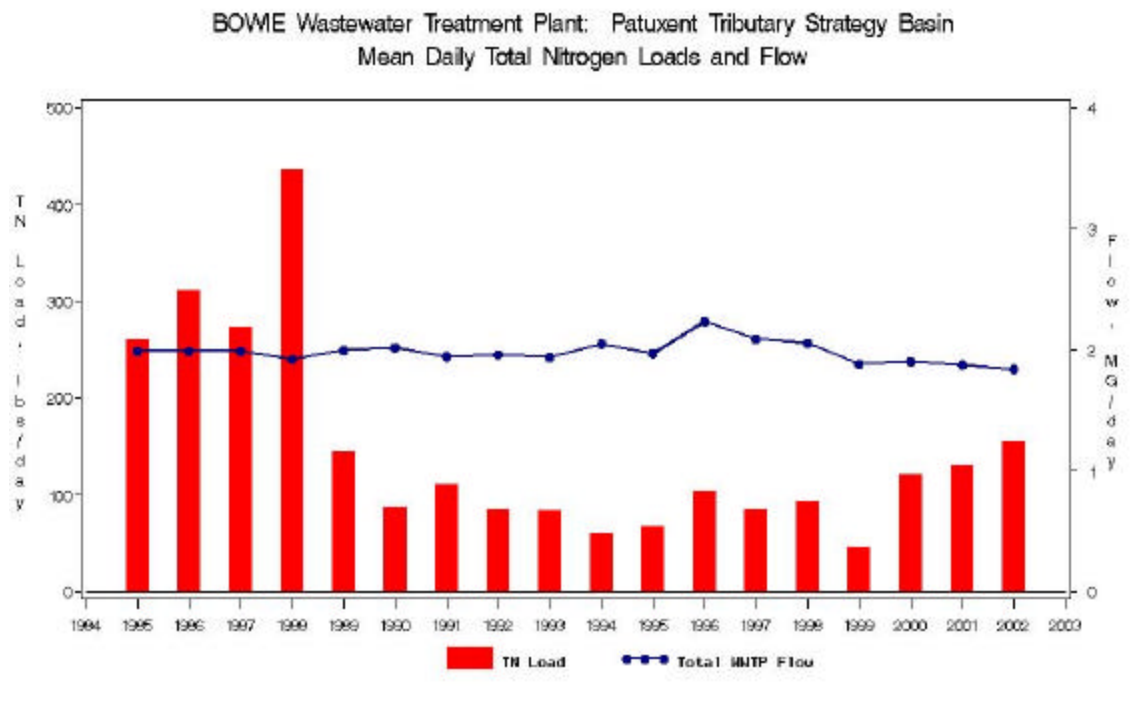
If an area is nutrient saturated, then both nitrogen and phosphorus are available in excess. In this case, if phytoplankton are exposed to appropriate water temperatures and sufficient light, they will grow. If an area is both nitrogen and phosphorus limited, then both nitrogen and phosphorus must be added to increase algal growth.

Managers can use the nutrient limitation model to predict which nutrient is limiting at a given location and use the information to assess what management approach might be the most effective for controlling excess phytoplankton growth. If an area is phosphorus limited, then reducing phosphorus will bring the most immediate reductions in phytoplankton growth. However, if nitrogen levels are not also reduced, the excess nitrogen that goes unused can be exported downstream. This excess nitrogen may reach an area that is nitrogen limited, fueling phytoplankton growth in that downstream area.

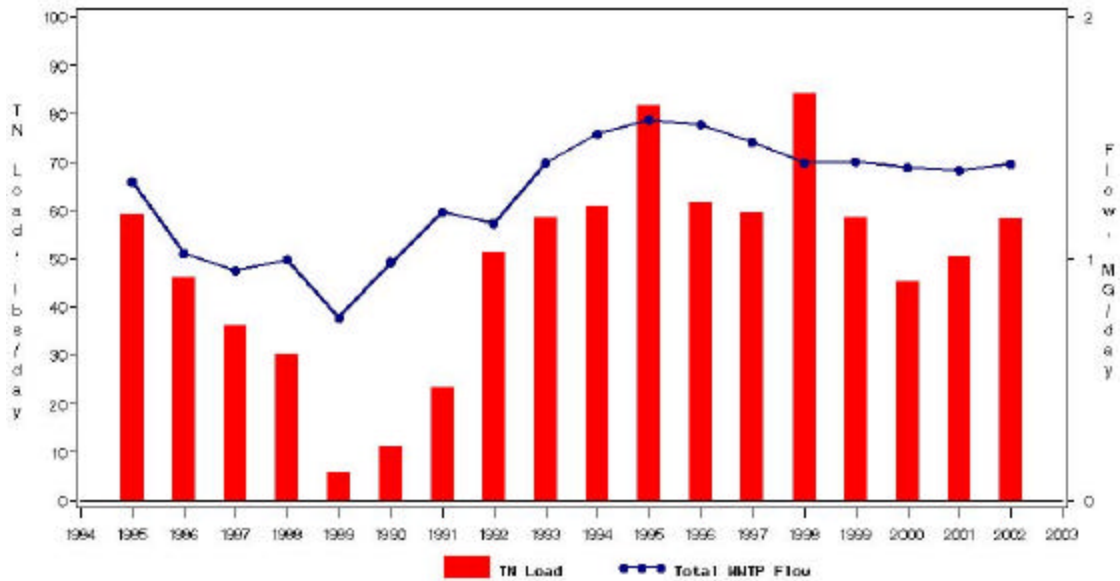
The nutrient limitation predictions are a valuable tool, but they must be used in conjunction with other water quality and watershed information to fully assess and evaluate the best management approach.

The nutrient limitation models were used to predict nutrient limitation for the twelve stations in the Patuxent Basin. Results for each station are summarized for the most recent three-year period (2000-2002) by season: winter (December-February), spring (March-May), summer (July-September) and fall (October-November). Overall, the upper river is largely nutrient saturated and seasonal patterns in nutrient limitation are controlled by riverflow (Fisher and Gustafson 2002). The lower river is largely nitrogen limited, probably due to sewage inflows with low Dissolved inorganic nitrogen to dissolved inorganic phosphorus ratios and lower variability in seasonal river flows (Fisher and Gustafson 2002). See Appendix B for details.

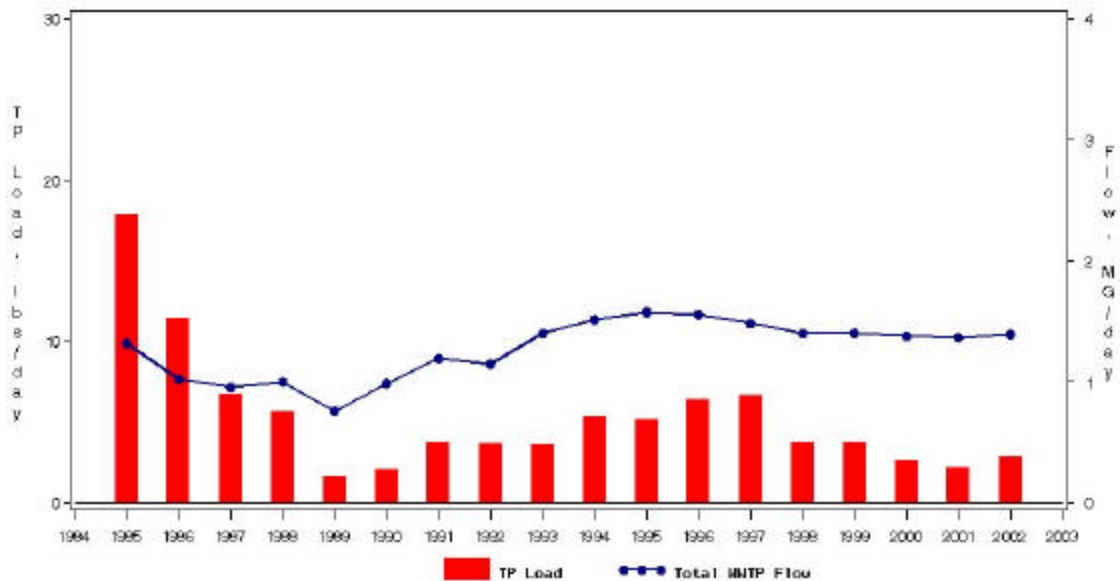
Appendix A – Nutrient Loadings from Major Wastewater Treatment Facilities in the Patuxent River Basin



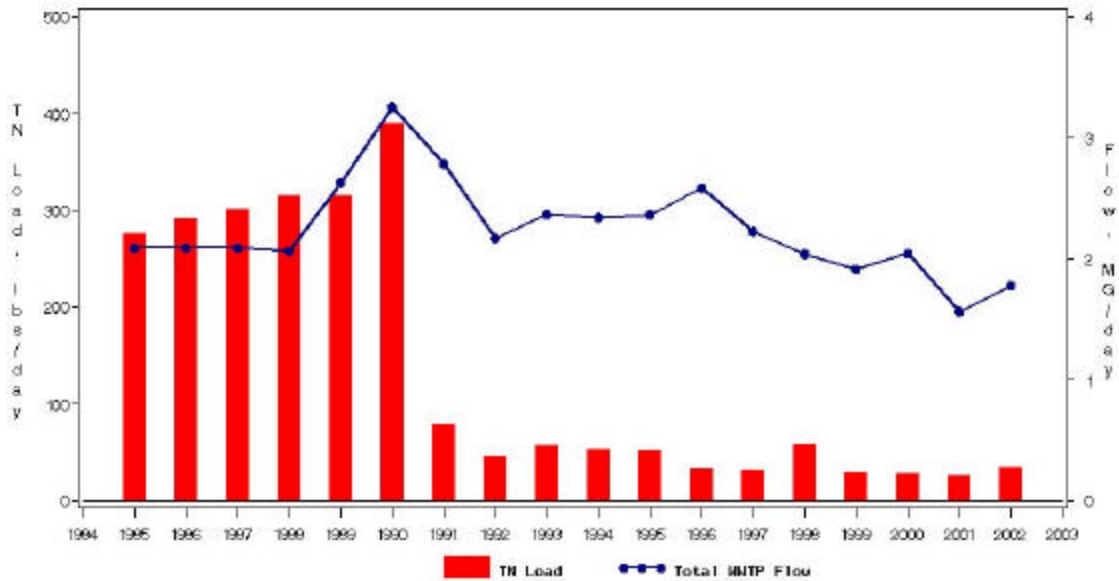
DORSEY RUN Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



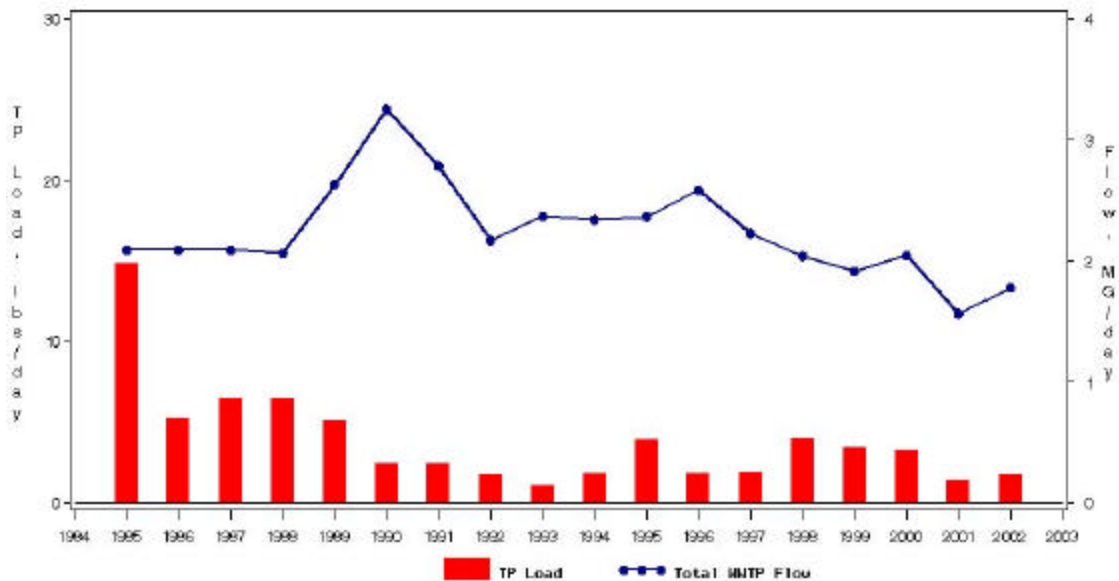
DORSEY RUN Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



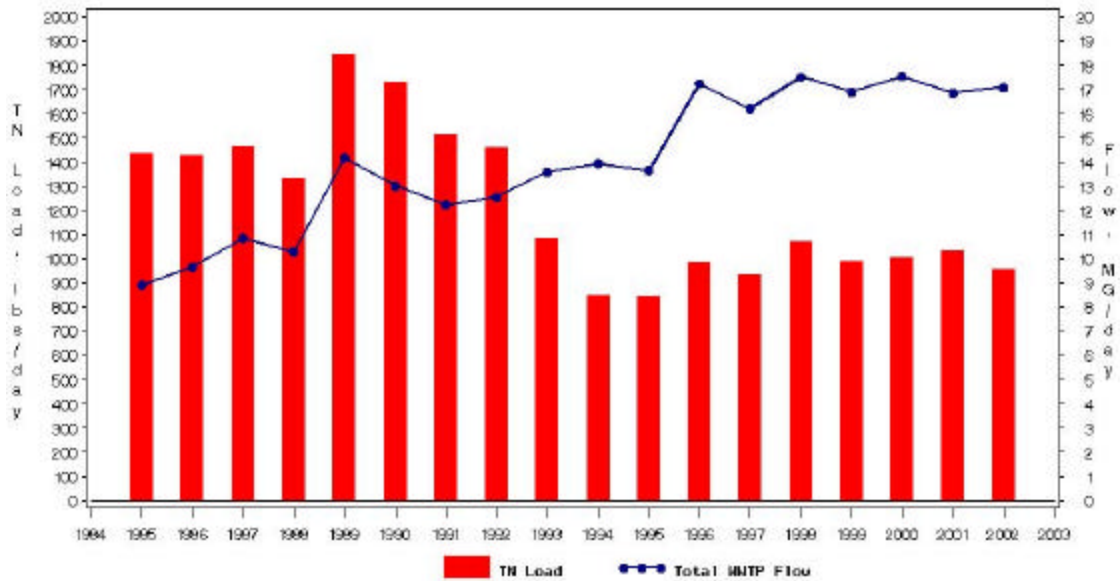
FORT MEADE Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



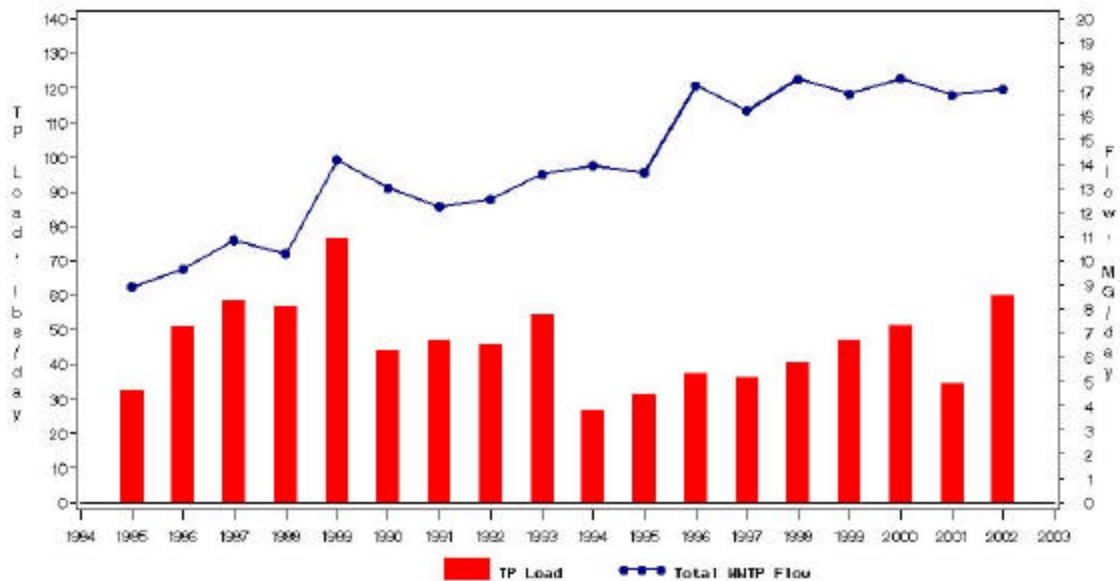
FORT MEADE Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



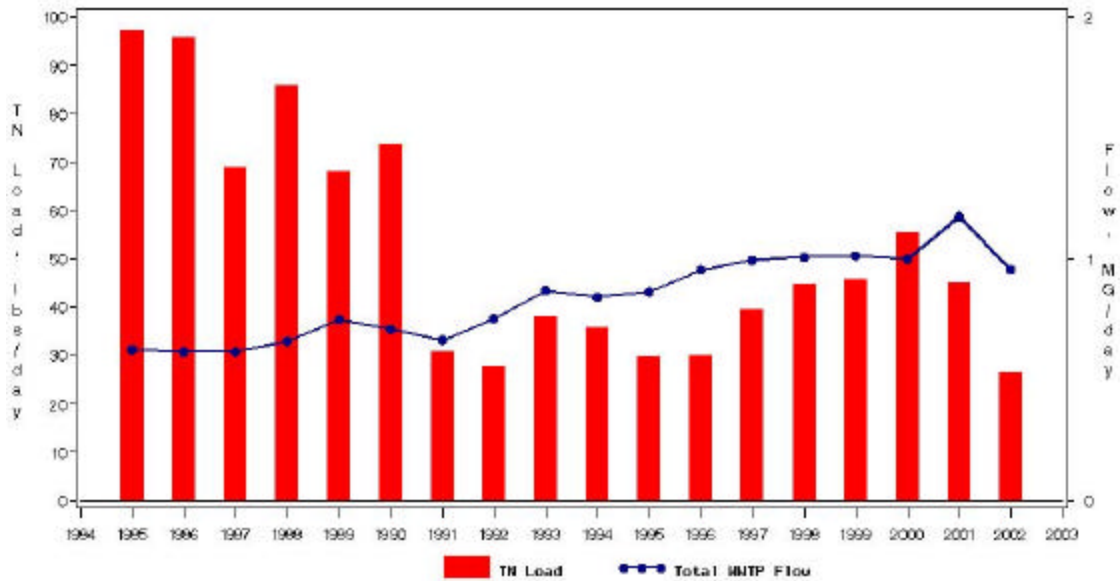
LITTLE PATUXENT Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



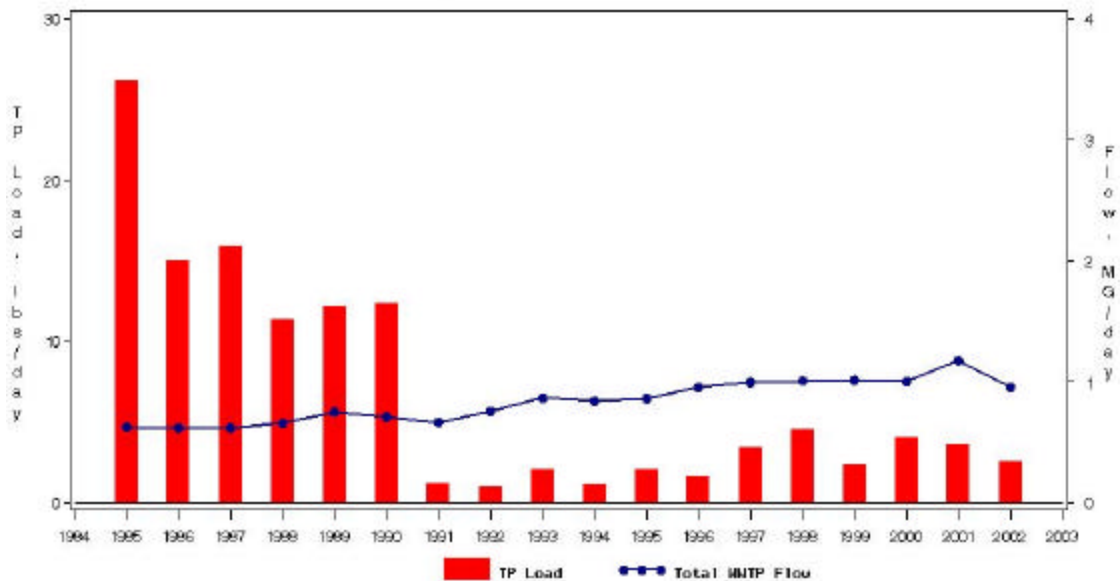
LITTLE PATUXENT Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



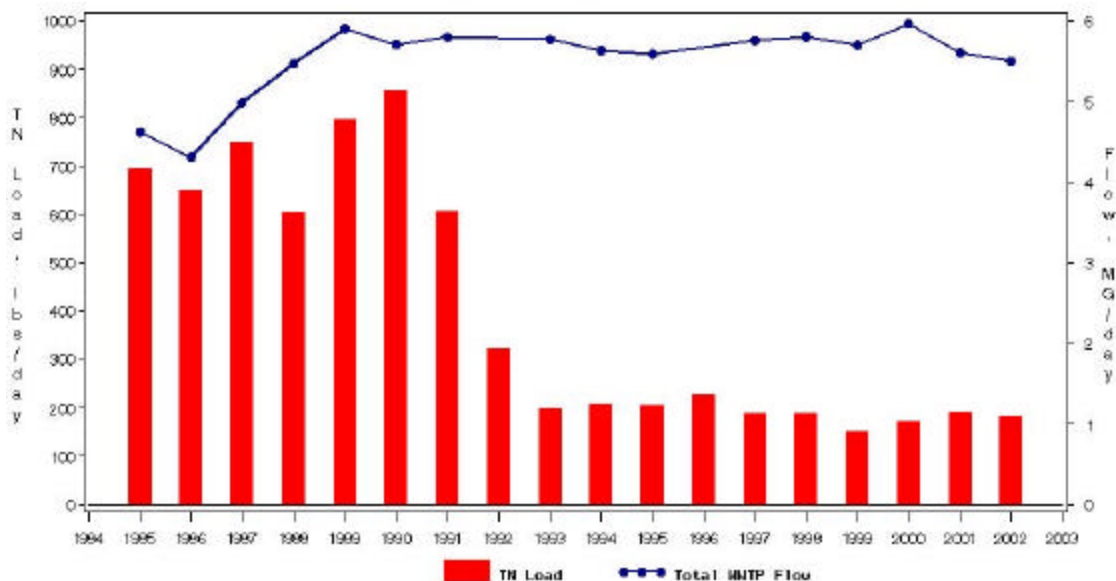
MARYLAND CITY Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



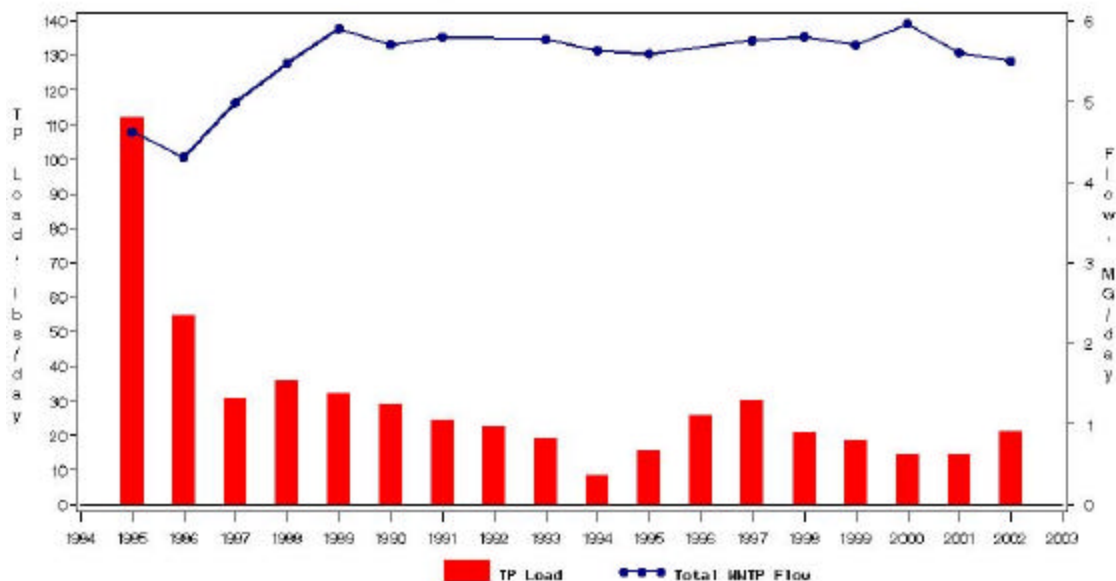
MARYLAND CITY Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



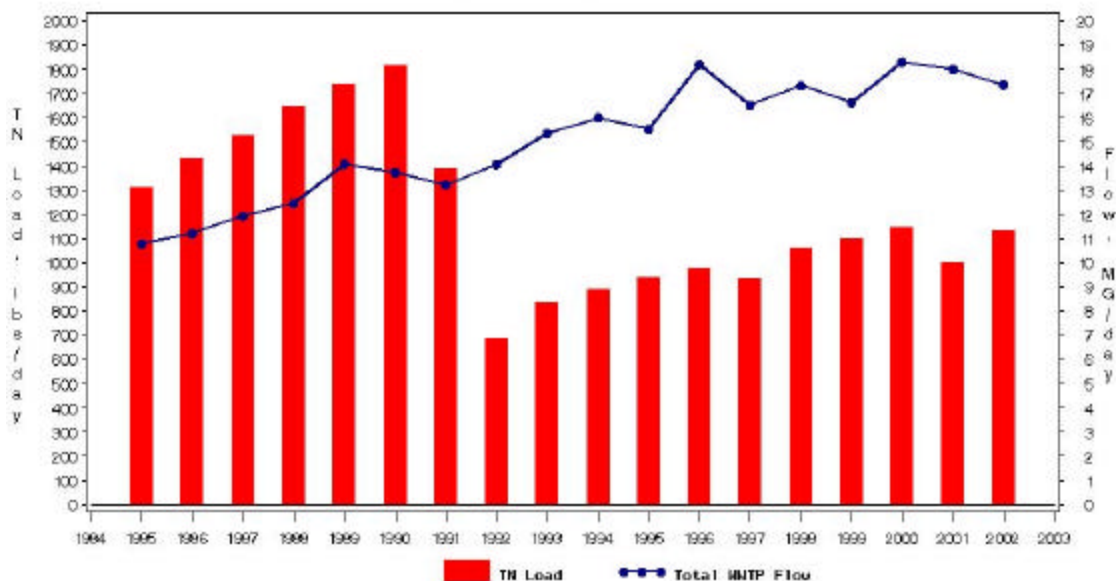
PARKWAY Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



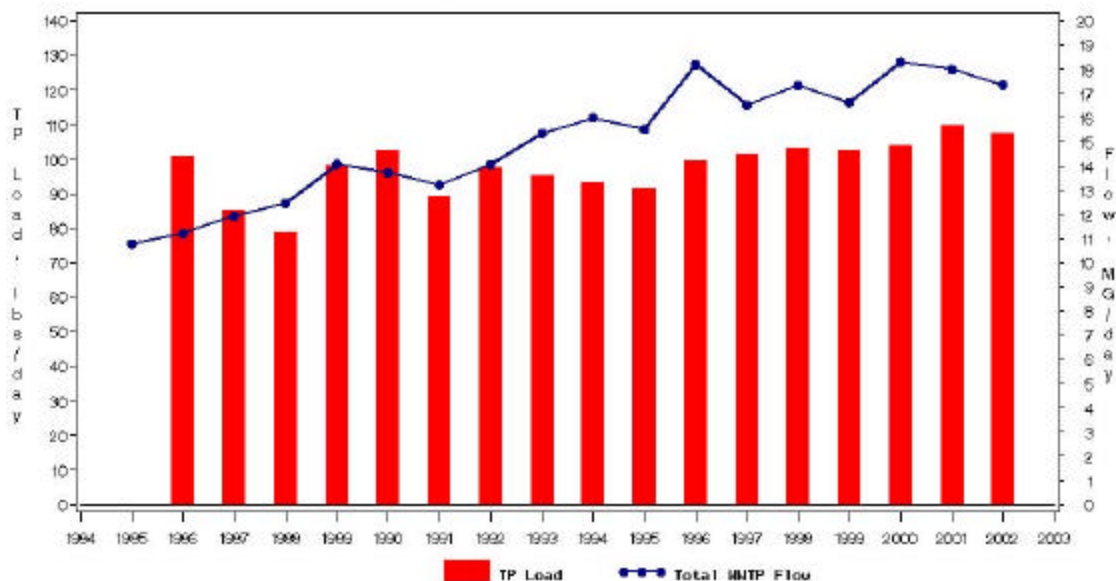
PARKWAY Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



WESTERN BRANCH Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



WESTERN BRANCH Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow

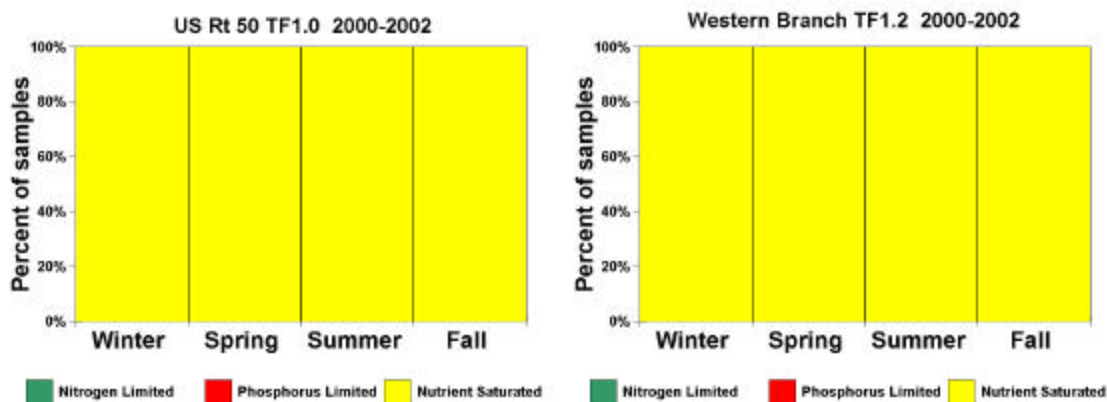


Appendix B – Nutrient Limitation Graphs for the Patuxent River Basin

The nutrient limitation models were used to predict nutrient limitation for the twelve stations in the Patuxent Basin. Results for each station are summarized for the most recent three-year period (2000-2002) by season: winter (December-February), spring (March-May), summer (July-September) and fall (October-November). Overall, the upper river is largely nutrient saturated and seasonal patterns in nutrient limitation are controlled by riverflow (Fisher and Gustafson 2002). The lower river is largely nitrogen limited, probably due to sewage inflows with low Dissolved inorganic nitrogen to dissolved inorganic phosphorus ratios and lower variability in seasonal river flows (Fisher and Gustafson 2002).

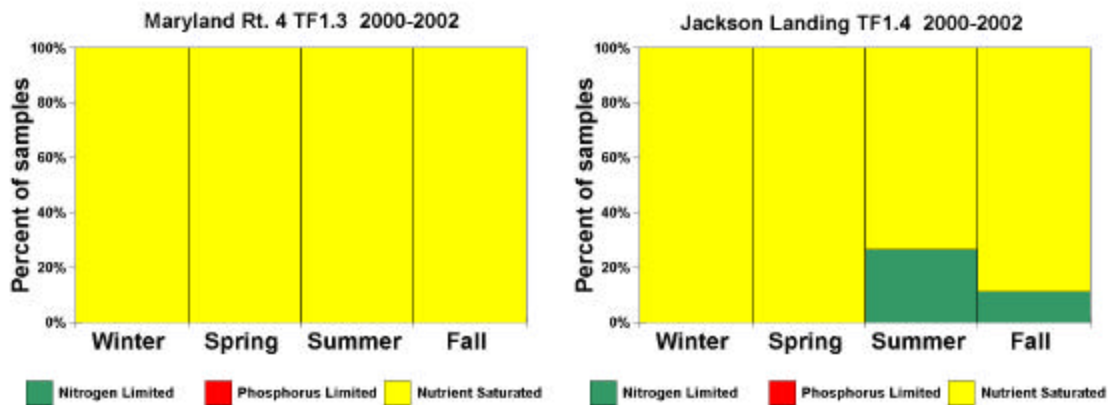
Managers can use these predictions to assess what management approach will be the most effective for controlling excess phytoplankton growth. Interpreting the results can be a little counter-intuitive, however. Remember that nitrogen limited means that phosphorus is in excess. Initially, it would seem that the best management strategy would be to reduce phosphorus inputs. However, it may actually be more cost effective to further reduce nitrogen inputs to increase the amount of ‘unbalance’ in the relative proportions of nutrients so that phytoplankton growth is even more limited. When used along with other information available from the water quality and watershed management programs, these predictions will allow managers to make more cost-effective management decisions.

US Rt. 50 (TF1.0) – Phytoplankton growth at this station is nutrient saturated (light limited or no limitation) at all times. Total nitrogen concentration is relatively fair and improving (decreasing). Total phosphorus concentration is relatively poor but improving (decreasing). The ratio of total nitrogen to total phosphorus is increasing. The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is relatively low, indicating that phosphorus is in excess relative to nitrogen, but dissolved nitrogen concentration is still very high. Further reductions in nitrogen concentrations will be needed, especially in summer and fall, before nitrogen limitation can occur at this station. Significant reductions in phosphorus will be needed to allow phosphorus limitation to occur in this portion of the Patuxent, but any reductions in phosphorus are important to reduce the amount of phosphorus being exported to areas downstream.



Western Branch (TF1.2) – Phytoplankton growth at this station is nutrient saturated (light limited or no limitation) at all times. Total nitrogen, total phosphorus and dissolved inorganic phosphorus concentrations are relatively good and all are improving (decreasing); dissolved inorganic nitrogen concentration is relatively good. The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is relatively low in summer and fall, but dissolved nitrogen concentration is still high. Further reductions in nitrogen concentrations will be needed, especially in summer and fall, before nitrogen limitation can occur at this station. Significant reductions in phosphorus will be needed to allow phosphorus limitation to occur in this portion of the Patuxent, but any reductions in phosphorus are important to reduce the amount of phosphorus being exported to areas downstream.

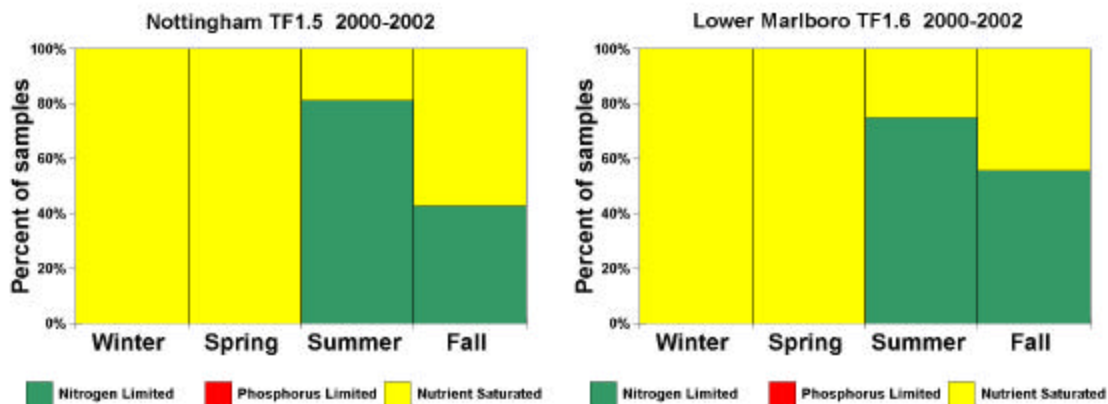
MD Rt. 4 (TF1.3) – Phytoplankton growth at this station is nutrient saturated (light limited or no limitation) at all times. Total and dissolved nitrogen concentrations are relatively poor but both are improving (decreasing). Total and dissolved inorganic phosphorus concentrations are relatively fair and both are improving (decreasing). The total nitrogen to total phosphorus ratio is decreasing. Further reductions in nitrogen concentrations will be needed, especially in summer and fall, before nitrogen limitation can occur at this station. Significant reductions in phosphorus will be needed to allow phosphorus limitation to occur in this portion of the Patuxent, but any reductions in phosphorus are important to reduce the amount of phosphorus being exported to areas downstream.



Jackson Landing (TF1.4) – Phytoplankton growth at this station is nutrient saturated (light limited or no limitation) 90% of the time and nitrogen limited less than 10% of the time. Summer growth is nitrogen limited about 25% of the time, and fall growth is nitrogen limited about 10% of the time. Total and dissolved inorganic nitrogen and dissolved inorganic phosphorus concentrations are relatively fair and all improving (decreasing). Total phosphorus concentration is relatively poor but improving (decreasing). The ratio of total nitrogen to total phosphorus and the ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus are both decreasing. The dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is relatively low in the summer, indicating that phosphorus is in excess relative to nitrogen. Further reductions in nitrogen, particularly in the spring and summer, may increase the duration of nitrogen

limitation. Significant reductions in phosphorus will be needed to allow phosphorus limitation to occur in this portion of the Patuxent, but any reductions in phosphorus are important to reduce the amount of phosphorus being exported to areas downstream.

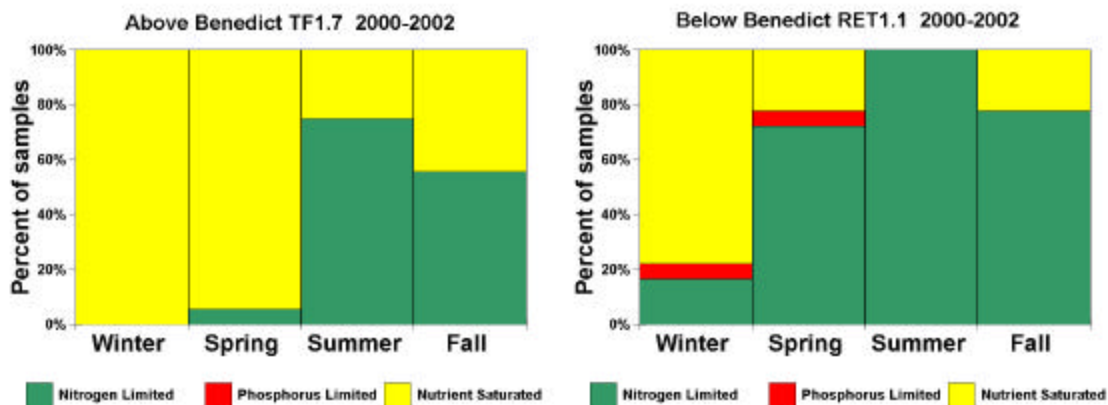
Nottingham (TF1.5) – On an annual basis, phytoplankton growth is nutrient saturated (light limited or no limitation) two-thirds of the time and nitrogen limited one-third of the time. Growth in the summer is nitrogen limited more than 80% of the time. Growth in the fall is nitrogen limited approximately 40% of the time. Total nitrogen concentration is relatively fair and dissolved inorganic nitrogen concentration is relatively good; both are improving (decreasing). Total phosphorus concentration is relatively poor and dissolved inorganic phosphorus concentration is relatively fair; both are improving (decreasing). The ratio of total nitrogen to total phosphorus and the ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus are both decreasing. The dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is relatively low in the summer and fall, indicating that phosphorus is in excess relative to nitrogen. Further reductions in nitrogen, particularly in the summer and fall, would increase the occurrences of nitrogen limitation. Much larger phosphorus reductions would be needed in winter and spring for phosphorus limitation to occur.



Lower Marlboro (TF1.6) – On an annual basis, phytoplankton growth is nutrient saturated (light limited or no limitation) two-thirds of the time and nitrogen limited one-third of the time. Growth in the summer is nitrogen limited 75% of the time. Growth in the fall is nitrogen limited almost 45% of the time. Total and dissolved inorganic nitrogen concentrations are relatively good and total and dissolved inorganic phosphorus concentrations are relatively poor, but all are improving (decreasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is decreasing; this ratio is relatively low in the summer and fall, indicating that phosphorus is in excess relative to nitrogen. Further reductions in nitrogen, particularly in the summer and fall, would increase the occurrences of nitrogen limitation. Much larger phosphorus reductions would be needed in winter and spring for phosphorus limitation to occur.

Above Benedict (TF1.7) – On an annual basis, phytoplankton growth is nutrient saturated (light limited or no limitation) 65% of the time and nitrogen limited 35% of the time.

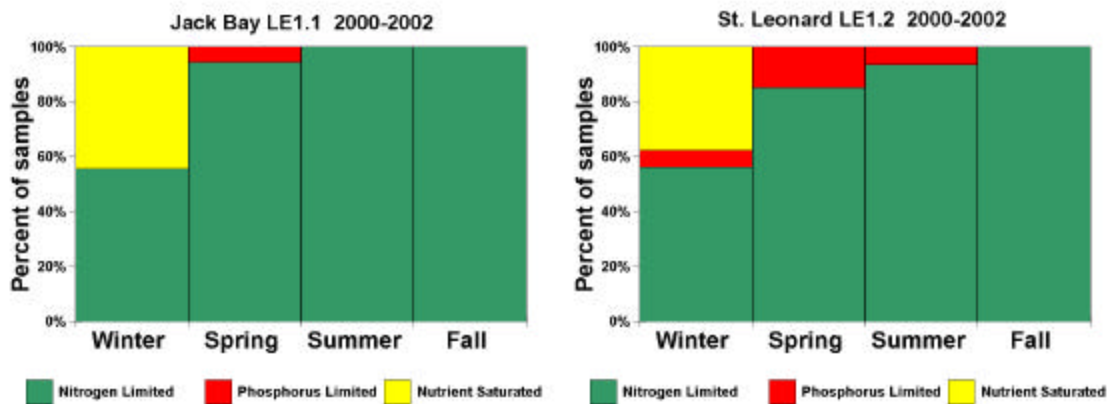
Growth in spring is occasionally nitrogen limited (approximately 5% of the time). Growth in the summer is nitrogen limited 75% of the time. Growth in the fall is nitrogen limited almost 45% of the time. Total nitrogen concentration is relatively good, dissolved inorganic nitrogen concentration is relatively fair, and total and dissolved inorganic phosphorus concentrations are relatively poor, but all are improving (decreasing). The ratio of total nitrogen to total phosphorus and the ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus are both decreasing. The dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is relatively low all year, but especially in summer and fall, indicating that phosphorus is in excess relative to nitrogen. Further reductions in nitrogen, particularly in the spring and fall, would increase the occurrences of nitrogen limitation. Much larger phosphorus reductions would be needed in winter and spring for phosphorus limitation to occur.



Below Benedict (RET1.1) – On an annual basis, phytoplankton growth is nitrogen limited more than 70% of the time and occasionally phosphorus limited (less than 5% of the time). Winter growth is nitrogen limited about 15% of the time and phosphorus limited 5% of the time. Spring growth is nitrogen limited more than 70% of the time and phosphorus limited 5% of the time. Summer growth is entirely nitrogen limited, and fall growth is nitrogen limited more than 75% of the time. Total nitrogen concentration is relatively fair, dissolved inorganic nitrogen concentration is relatively good, and total and dissolved inorganic phosphorus concentrations are relatively poor; all are improving (decreasing). The ratio of total nitrogen to total phosphorus and the ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus are both decreasing. The dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is relatively low, indicating that phosphorus is in excess relative to nitrogen. Further reductions in nitrogen have the potential for limiting phytoplankton growth in all seasons. Reductions in phosphorus, particularly in the summer and fall, will bring the system into better balance.

Jack Bay (LE1.1) – On an annual basis, phytoplankton growth is nitrogen limited more than 90% of the time and rarely phosphorus limited (less than 5% of the time). Winter growth is nitrogen limited 55% of the time. Spring growth is nitrogen limited almost 95% of the time and phosphorus limited less than 5% of the time. Summer and fall growth is entirely nitrogen limited. Total and dissolved inorganic nitrogen concentrations

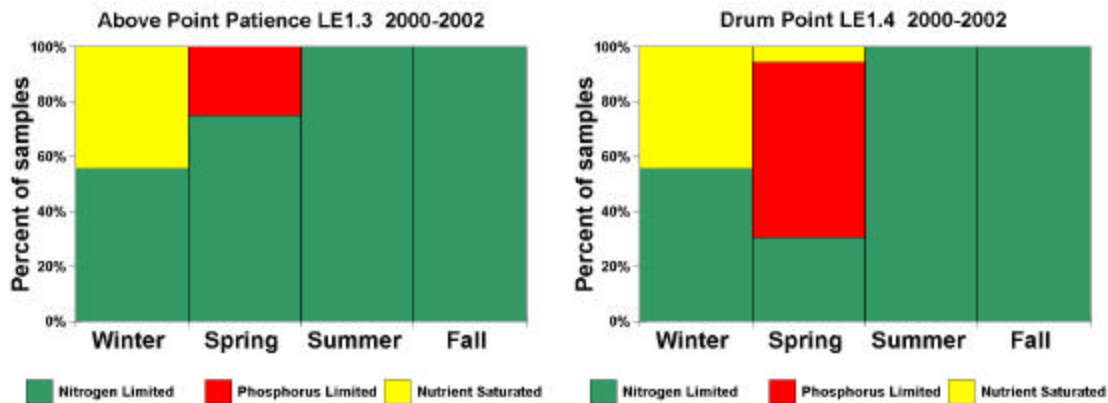
are relatively good and total and dissolved inorganic phosphorus concentrations are relatively fair, and all are improving (decreasing). Total nitrogen to total phosphorus and dissolved inorganic nitrogen to dissolved inorganic phosphorus ratios are both decreasing. The dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is relatively very low, especially in the summer and fall, due to relatively high phosphorus concentrations. Continued reductions in nitrogen will help increase the occurrences of nitrogen limitation in the winter and spring, and further suppress algal growth throughout the year. Reductions in phosphorus concentrations, particularly in the spring, would help bring the system into better balance and allow for phosphorus limitation of growth as well.



St. Leonard (LE1.2) – On an annual basis, phytoplankton growth is nitrogen limited more than 85% of the time and phosphorus limited almost 10% of the time. Winter growth is nitrogen limited approximately 55% of the time and phosphorus limited about 5% of the time. Spring growth is nitrogen limited 85% of the time and phosphorus limited 15% of the time. Summer growth is nitrogen limited almost 95% of the time and otherwise is phosphorus limited. Fall growth is entirely nitrogen limited. Total nitrogen, dissolved inorganic nitrogen and total phosphorus concentrations are all relatively good and improving (decreasing); dissolved inorganic phosphorus concentration is relatively fair and improving (decreasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is decreasing; this is relatively very low, especially in the summer and fall, due to relatively high phosphorus concentrations. Continued reductions in nitrogen will help increase the occurrences of nitrogen limitation in the winter and spring, and further suppress algal growth throughout the year. Continued reductions in phosphorus concentrations, particularly in the spring, would help bring the system into better balance and allow for increased phosphorus limitation of growth as well.

Above Pt. Patience (LE1.3) – On an annual basis, phytoplankton growth is nitrogen limited almost 85% of the time and phosphorus limited almost 10% of the time. Winter growth is nitrogen limited 55% of the time and otherwise nutrient saturated (light limited or no limitation). Spring growth is nitrogen limited more than 75% of the time and phosphorus limited 25% of the time. Summer and fall growth is always nitrogen limited. Total nitrogen, dissolved inorganic nitrogen, and dissolved inorganic phosphorus concentrations are all relatively good and improving (decreasing); total phosphorus

concentration is relatively good. The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is decreasing; this ratio is relatively very low, especially in the summer and fall due to high phosphorus concentrations. Continued reductions in nitrogen will help increase the occurrences of nitrogen limitation in the winter and spring, and further suppress algal growth throughout the year. Continued reductions in phosphorus concentrations, particularly in the spring, would help bring the system into better balance and allow for increased phosphorus limitation of growth as well.



Drum Point (LE1.4) – On an annual basis, phytoplankton growth is nitrogen limited almost 70% of the time and phosphorus limited more than 20% of the time. Winter growth is nitrogen limited 55% of the time and is otherwise nutrient saturated (light limited or no limitation). Spring growth is phosphorus limited approximately 65% of the time and nitrogen limited approximately 30% of the time. Summer and fall growth is entirely nitrogen limited. Total nitrogen and dissolved inorganic nitrogen concentrations are relatively good and improving (decreasing). Total phosphorus concentration is relatively good and dissolved inorganic phosphorus concentration is relatively fair. The ratio of total nitrogen to total phosphorus and the ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus are both decreasing. The dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is relatively low in the winter, summer and fall. Continued reductions in nitrogen will help increase the occurrences of nitrogen limitation in the winter and spring, and further suppress algal growth throughout the year. Reductions in phosphorus would increase phosphorus limitation in the spring.

Appendix C – References

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